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Planetary Rover and Space Platform Servicing — Simulation Tools and Network Based Operations

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Workshop WS4: The Use of Simulation as Tool for Robotics Research, Development and Applications, and Computer Networked Robotics

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Outline

- Motivation from Future NASA Missions
- Ground Control of Space Platform Servicing
  - JPL-ETL Trans-Pacific Telerobotics
  - JPL-JSC Cross-Country Telerobotics
  - Task Lines and Motion Guides
- Earth-Based Control of Long-Duration Planetary Rover Missions
  - Web Interface for Telescience (WITS)

Motivation from Future NASA Missions

There are a wide variety of planned and potential future NASA missions which will benefit from advanced simulation and networked telerobotics systems.

- Ground control of Space Station robotics systems
- Ground control of unmanned space platform servicing
- Earth-based control of lunar and planetary rover missions
- Earth-based control of planetary balloon missions
- Etc.

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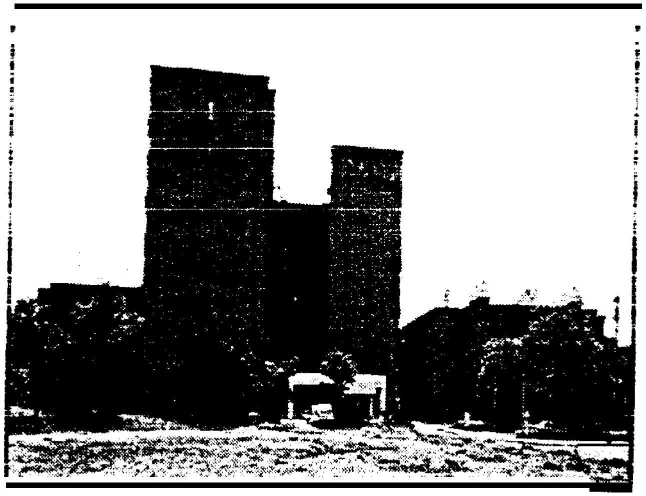
Ground Control of Space Platform Servicing

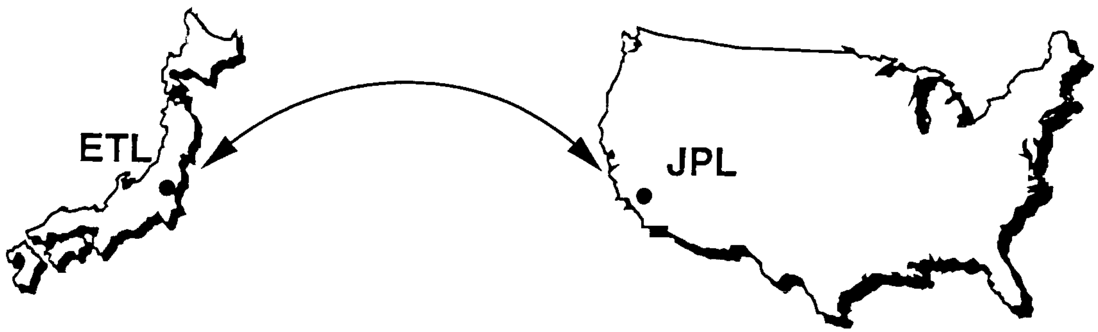
- Ground control will be used for telerobotic servicing of both manned, e.g. Space Station, and unmanned, e.g. satellites, space platforms.
- Ground control systems must be very safe since the space-based systems they will interact with are very expensive to develop and launch.
- The space-based system must be very flexible to satisfy various servicing needs - and anomalies in the space-based hardware.
- The ground-based systems must be capable of utilizing the complete capability of the space-based systems, but ensure safety.
- Space Station robotic systems will be controllable from both the ground and Space Station architecture and simulation tools are needed which support ground-based assistance of Space Station based operation.

JPL-ETL Trans-Pacific Telerobotics

Japan/AIST-MITI:
Electrotechnical Laboratory



USA/NASA:
Jet Propulsion Laboratory



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JPL-ETL Trans-Pacific Telerobotics

JPL Distributed Space Telerobotics task:

- Managed by JPL Robotics and Mars Exploration Office
- Funded by NASA Office of Advanced Concepts and Technology, Telerobotics Program

ETL Study on Interoperation Technology for Long Distance Telerobot task:

- Managed by ETL International Research Cooperation Office
- Funded by AIST International Research and Development Cooperation Division, Specific International Joint Research Projects

Participants:

- Electrotechnical Laboratory:
  - Shigeoki Hirai
  - Yujin Wakita
  - Kazuo Machida
- Kawasaki Heavy Industries:
  - Fumio Yasumoto
  - Hiroaki Ujiie
  - Takashi Katsuragawa
  - Toshiyuki Itoko
  - Kenji Ogimoto
- Jet Propulsion Laboratory:
  - Paul Backes
  - Stephen Peters

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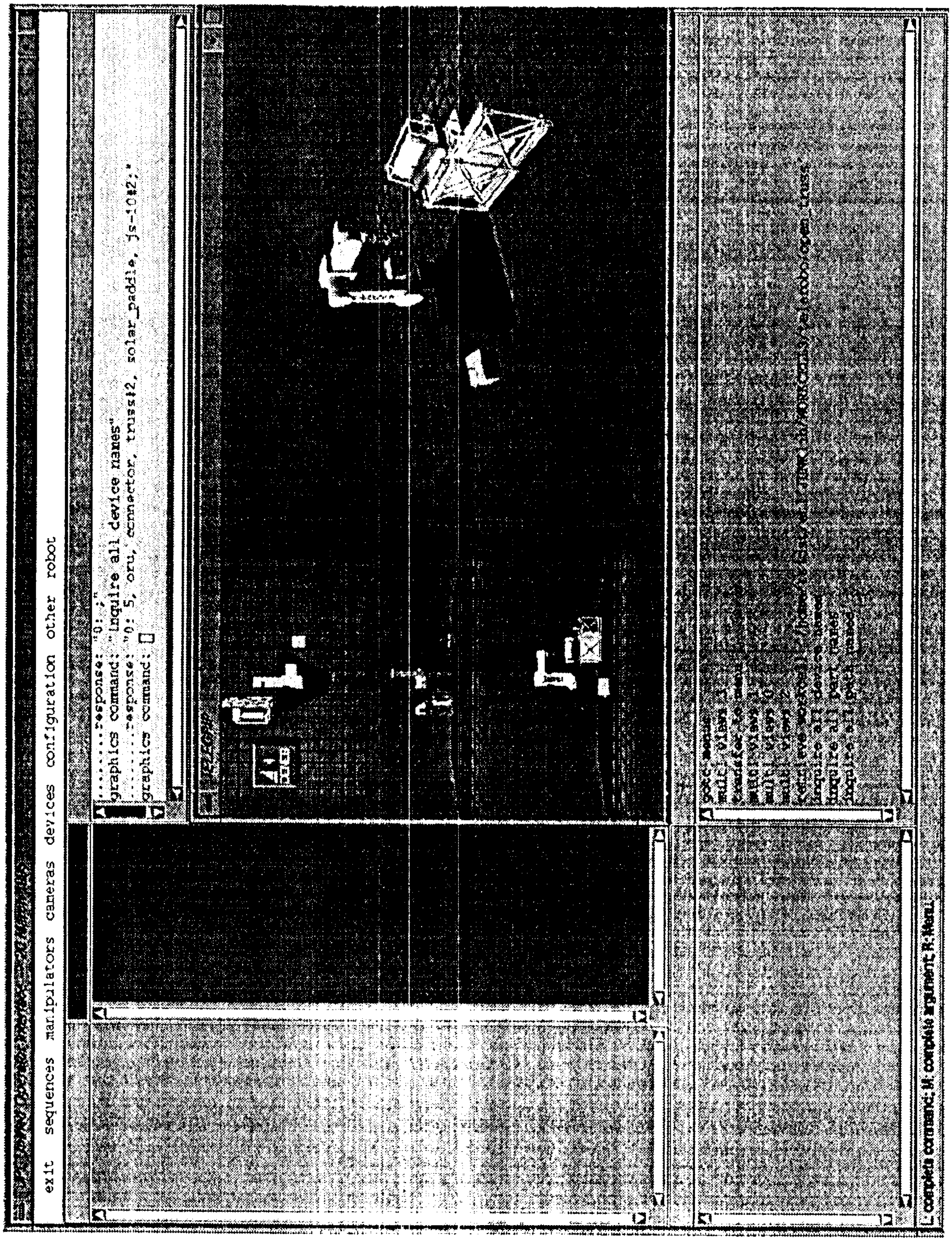
JPL-ETL Trans-Pacific Telerobotics

- An ETL-located robotic system was controlled from JPL using the JPL-developed Unified Operator Interface.
- Demonstrated space structure deployment and Orbital Replacement Unit installation tasks.
- An ISDN communication link was used between JPL and ETL for commands and image transfer; the communications capacity was 56 k-bps.
- Cisco routers connected the ISDN line and TCP/IP was used as the communication protocol.
- Control of the remote system at ETL was done using the MEISTER (Model Enhanced Intelligent and Skillful Teleoperational Robot) system.

When a command is selected for execution, it is automatically simulated first. A command specifies only the action of the robot. The Unified Operator Interface automatically generates the corresponding pan, tilt and zoom position commands for the camera at ETL. After the viewing and robot motion commands are simulated, the interface requests confirmation from the operator before sending them to the real camera. When the camera motion is complete, a video image from the selected camera is sent from ETL to JPL and displayed.

Unified Operator Interface

- Implemented in Lisp.
- Used TeleGRIP graphics from Deneb Robotics as a separate process.
- One operator interface infrastructure (UOI) was used to control various robotics systems including JPL Remote Surface Inspection laboratory Robotics Research 7 DOF arm, JPL serpentine manipulator, Electrotechnical Laboratory K III robot, Rocky 3 and Rocky 7 rovers, and Mars lander manipulator.
- Commands in command sequences included setup commands, commands to various devices, and commands for both simulation and real arm execution.
- inclusion of setup commands was useful for initialization of system which was previously done all interactively.



Unified Operator Interface for JPL-ETL remote operation

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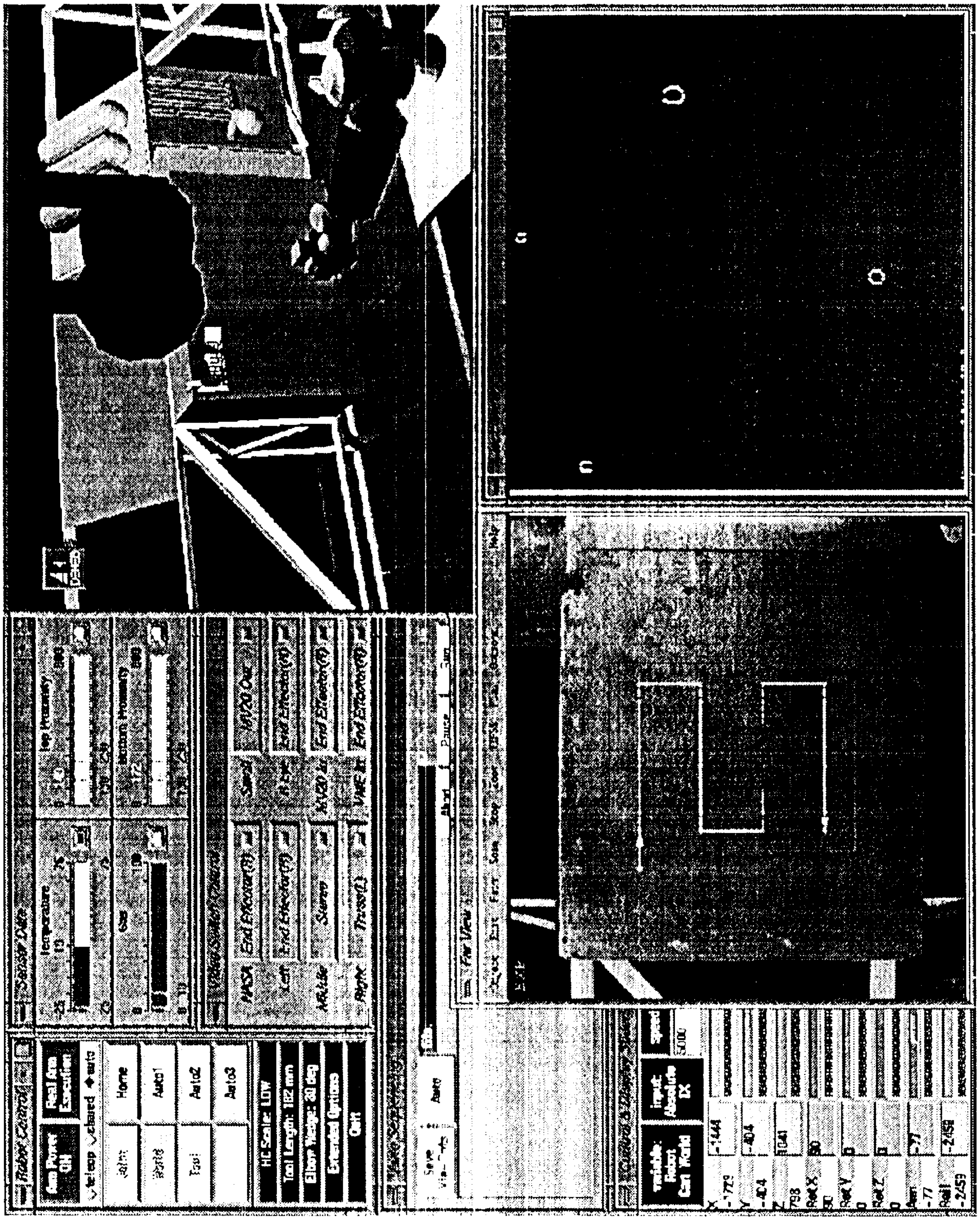
JPL-JSC Cross-Country Telerobotics

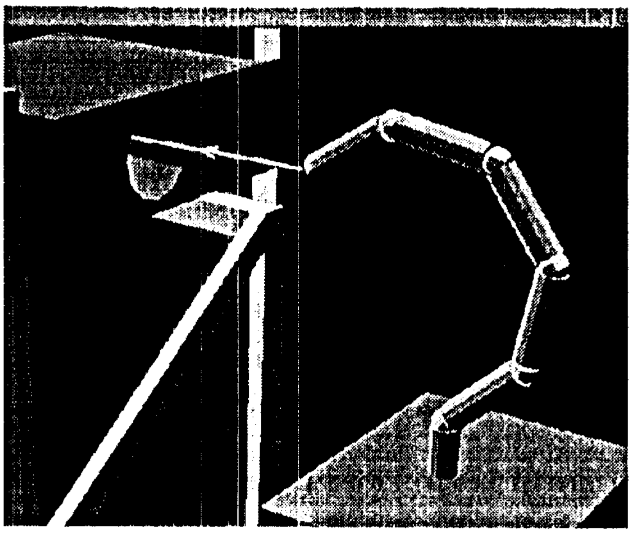
- Demonstrated Space Station telerobotic inspection technologies by controlling JPL Remote Surface Inspection laboratory system (in Pasadena, California) from Johnson Space Center (in Houston, Texas).
- Used socket communication over internet for commands and data.
- Used Netscape for continuous image update of RSI lab at JSC.



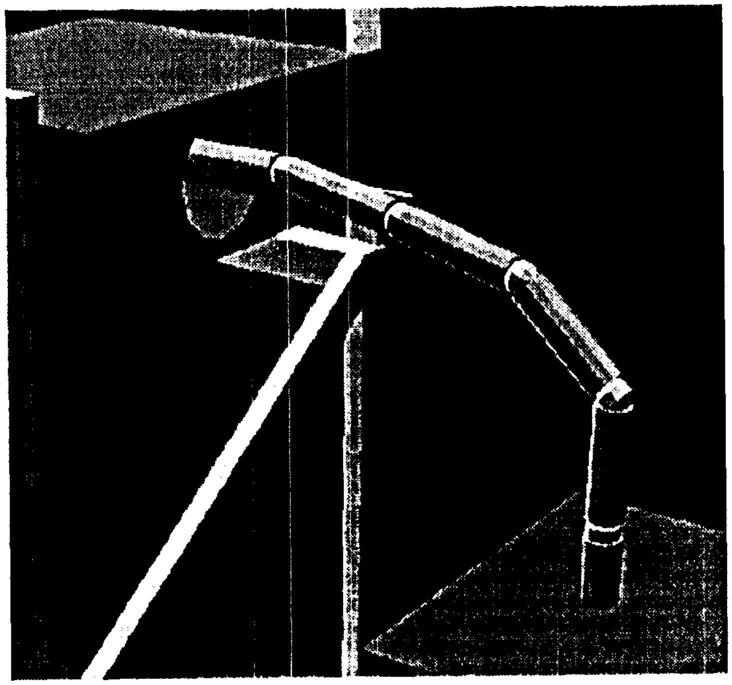
Remote Surface Inspection system operator interface

Motion Guides

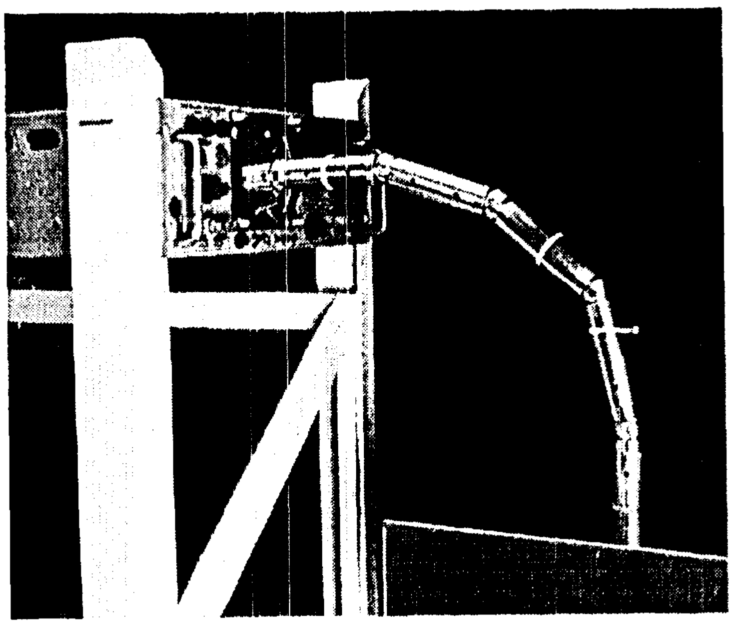
- Motion guides is a new paradigm for teleoperation of a robot where the path is teleoperated rather than the robot, and the robot is constrained to follow the path.
- The paths are generated, displayed and modified in a graphical environment.
- Continuous commands to the robot are only one dimensional: forward, back, or halt along the motion guide.
- A motion guide shows a complete representation of the robot path in a single snapshot graphics representation.



Simulated snake robot at start of motion guide



Simulated snake robot at end of motion guide



Real snake robot at end of motion guide inside cavity

Motion Guides, Cont.

- Path generation can be done in various ways, e.g., sample the path of a simulated robot which is teleoperated in a graphics environment or concatenate path segments which are each generated separately and given consistent transition conditions -- path points could be attached to physical points in the environment such as approach locations to objects or inspection points.

- The orientational component of the path can be represented in various ways, e.g., draw the robot gripper at various locations along the path, draw an iconic gripper at various locations along the path showing the direction and plane of the gripper along the path.

- The arm plane of a redundant robot can be represented as a series of vectors attached along the motion guide with direction normal to the arm plane.

- The path can be easily modified both before and while the robot is moving along it. A robot is constrained to follow the motion guide so when the motion guide is moved by the operator, the graphical robot, and corresponding real robot, move along a minimal normal distance to stay on the motion guide.

- Collision detection and avoidance can be done continuously for the entire path rather than only for the current simulated or real robot position.

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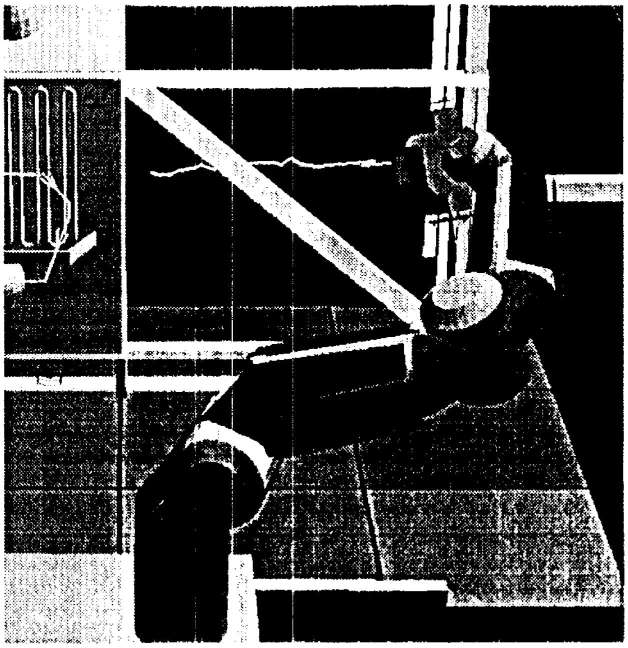
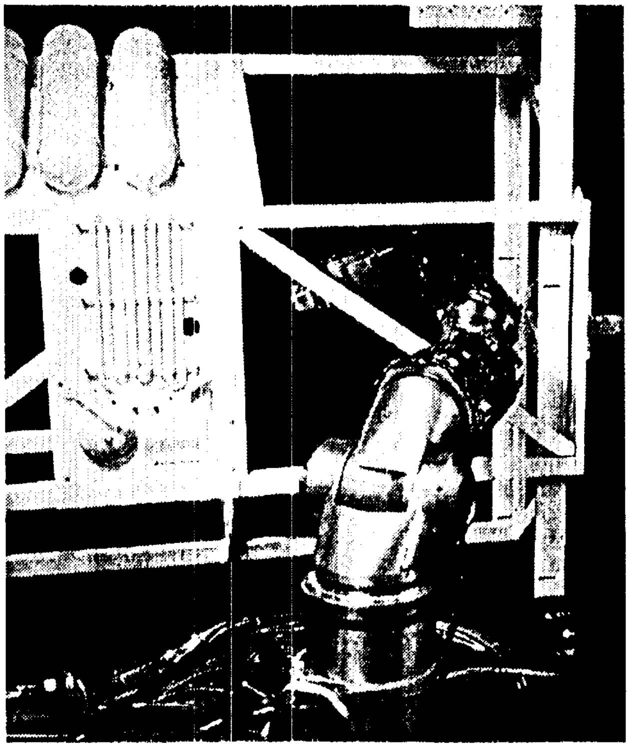
Operator teleoperating a motion guide

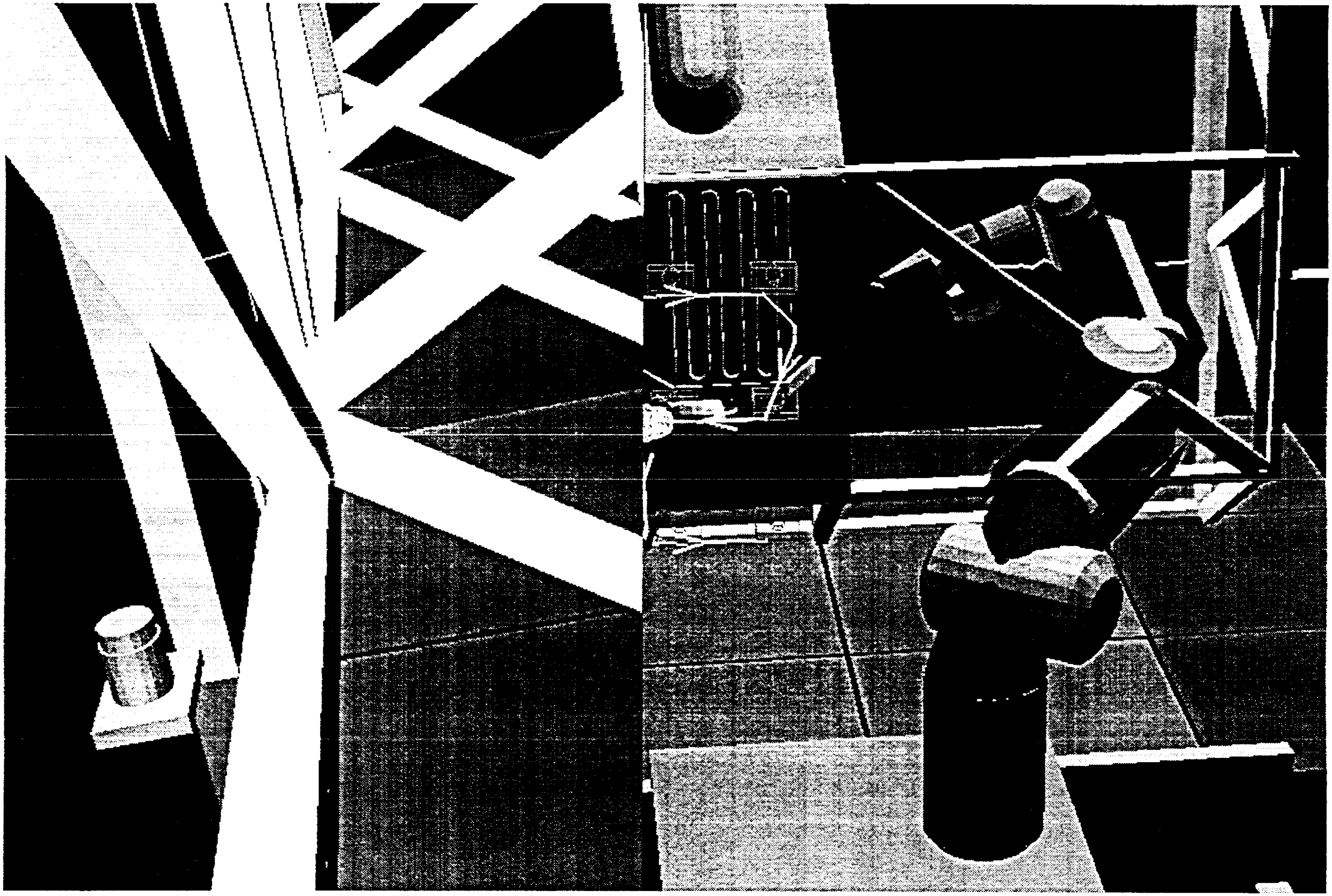
Operator commanding motion along a motion guide



Simulated robot at beginning of motion guide



Robot near end of motion guide



Simulated robot near end of motion guide; left view is from gripper camera viewpoint

Task Lines

- Task lines are visual representations of command sequences where visual icons representing subtasks are attached at different points on motion guides.
- Task lines provide programming within the graphical environment.
- A list of icons representing various subtasks can be provided within the graphical environment which the operator can select and drag to desired points on the motion guide.
- The operator will be able to modify the positions of the icons On the motion guides as well as modify the motion guides.
- The operator will be able to select an icon and then be presented with a panel which describes the associated command or sub-sequence and allow the operator to input parameters or modify the associated subtask.
- Icons may have generic shapes for generic types of commands, but then have variations of the generic icon shapes to represent variations of generic command types.

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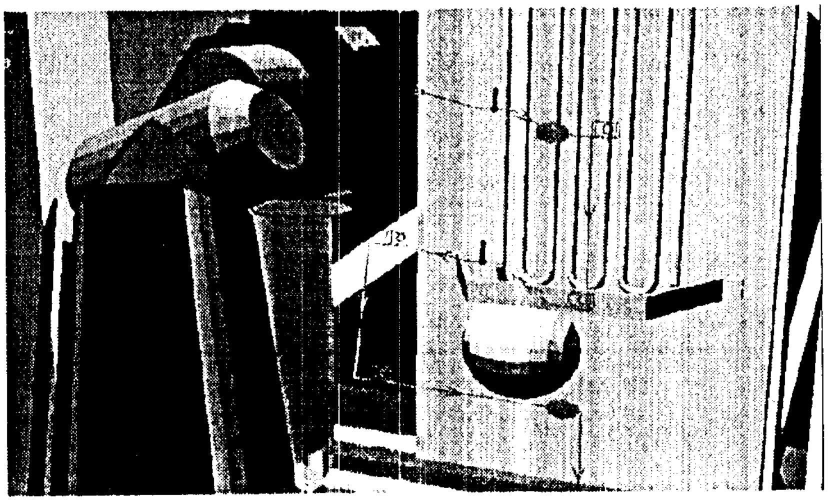
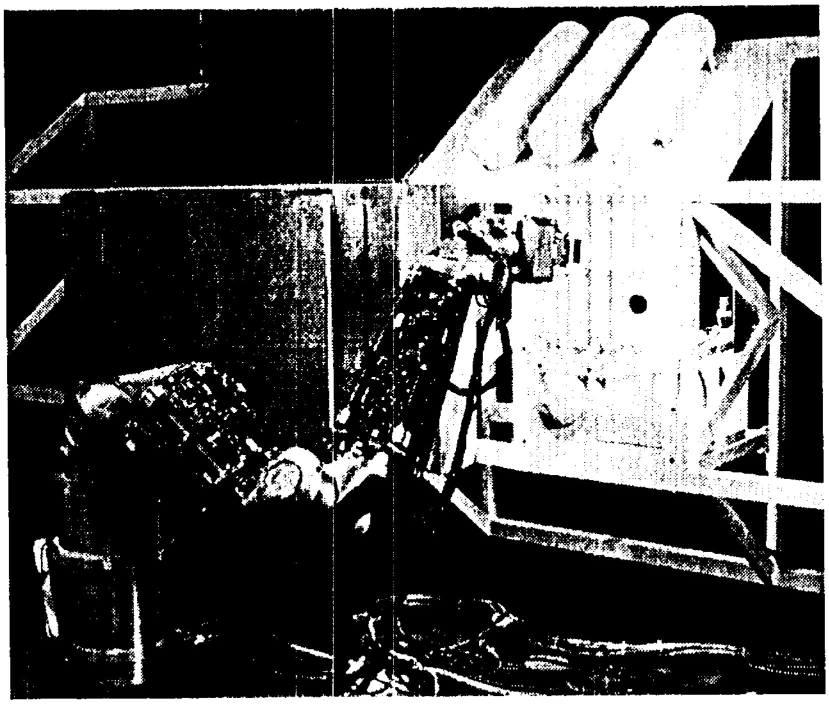
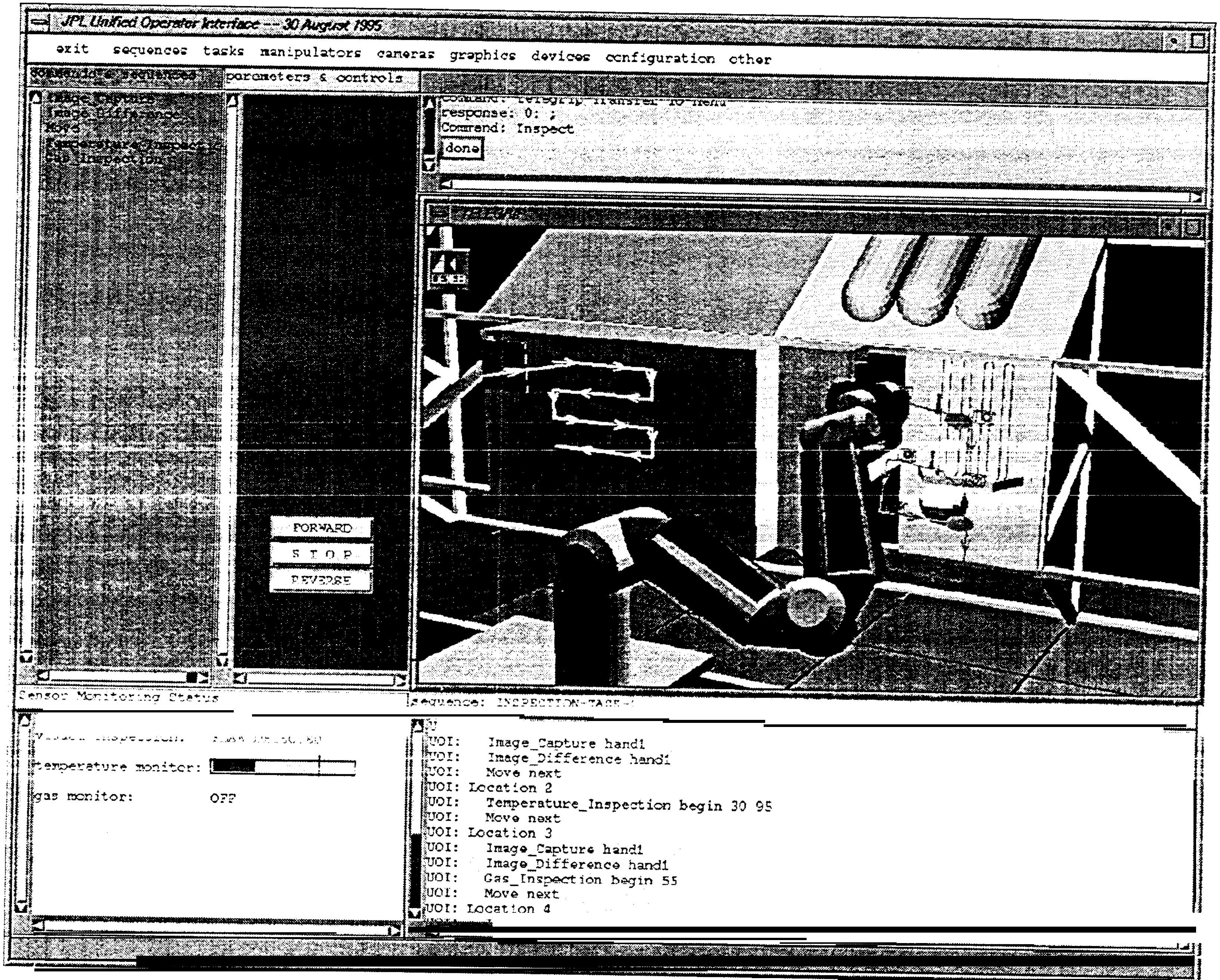


Task line for visual, temperature, and gas inspection



Robot executing task line



Unified Operator Interface with task line and corresponding command sequence

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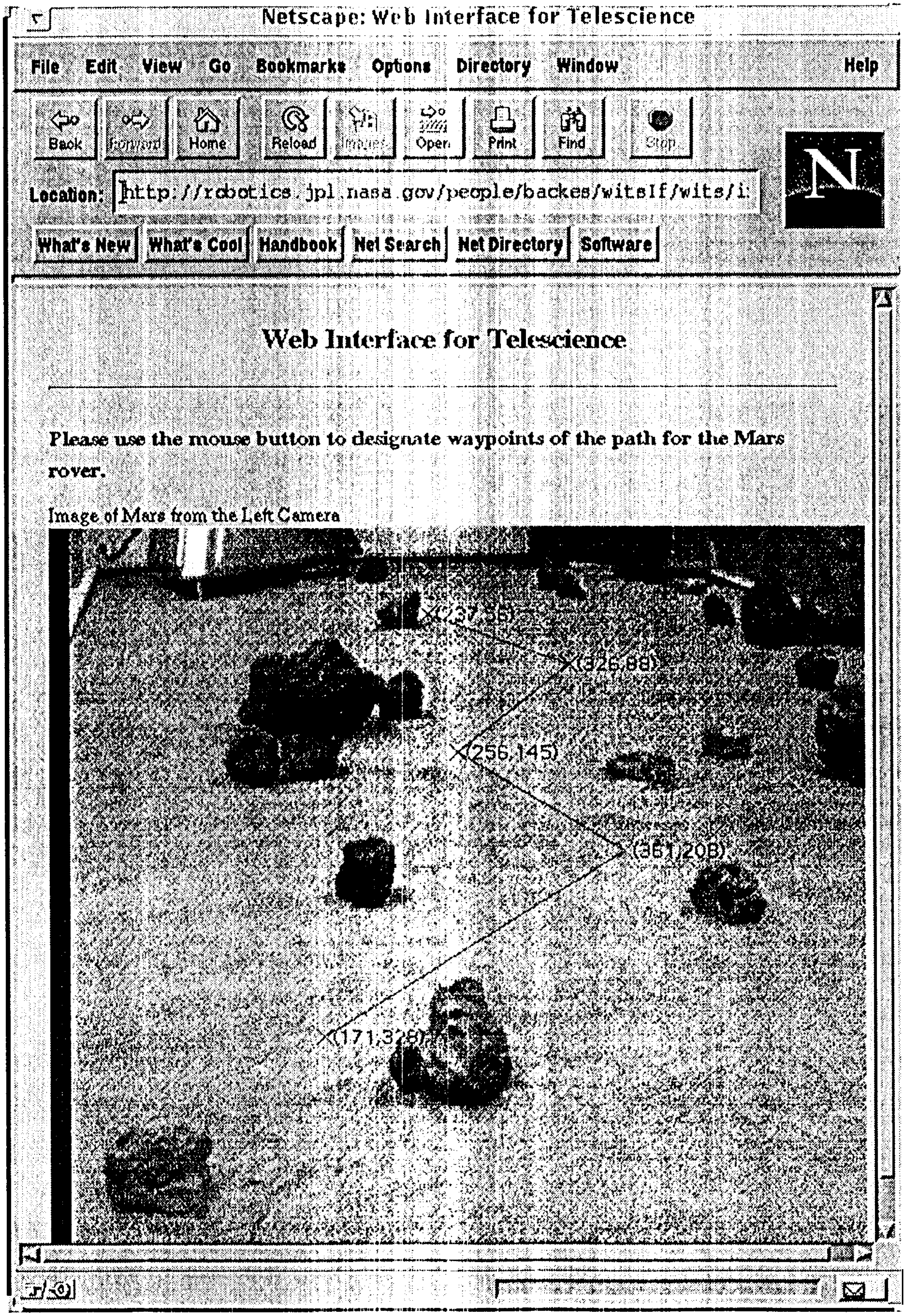
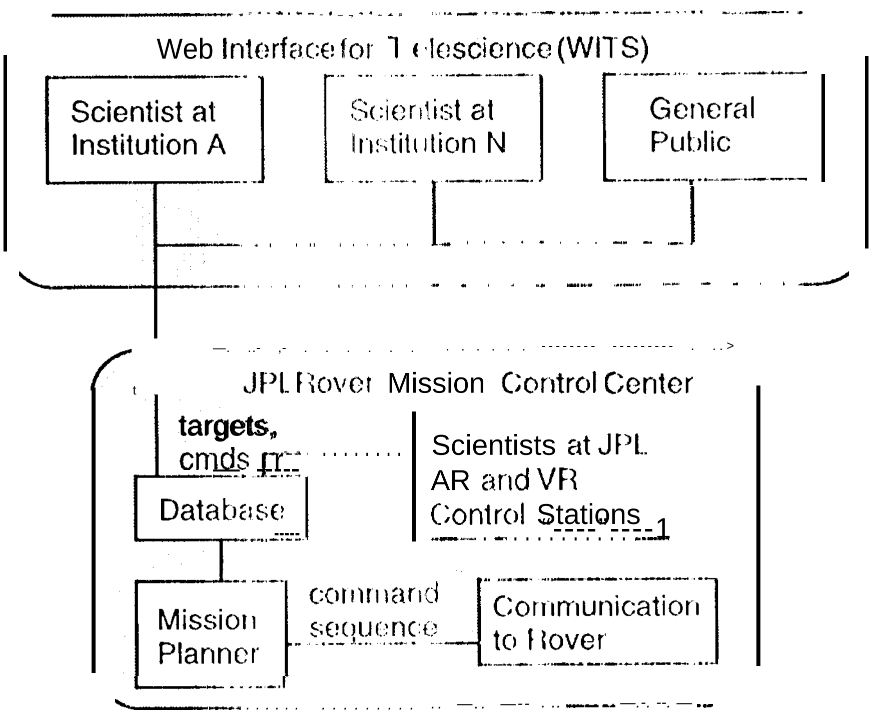
Web Interface for Telescience (WITS)

- Web interface will enable scientists at numerous locations to participate daily in long-duration planetary rover missions, e.g. Mars in 2001.
- Enable scientists at home institutions to view downlink data and submit science target and science command requests.
- Waypoint selection will be for Mission Planner mode only.
- Public version 1.0 available on Web now at http://robotics.jpl.nasa.gov/tasks/scirover/opint/wits/index.html
- Will show icons at science targets identified with scientists which selected the targets, as well as current mission path.
- Will add command generation and image selection panels, mission plan view, editing of science targets and waypoints, etc.
- Mission plan view image is a circular overhead graphic view of a panoramic scene with waypoints and science targets overlayed on an elevation or feature map.
- Implemented primarily using Java language.


Netscape: Web Interface for Telescience
File Edit View Go Bookmarks Options Directory Window Help
Back Forward Home Reload Images Open Print Find Stop
Location: http://robotics.jpl.nasa.gov/people/backes/witsIf/wits/i
What's New What's Cool Handbook Net Search Net Directory Software
Web Interface for Telescience
Please use the mouse button to designate waypoints of the path for the Mars rover.
Image of Mars from the Left Camera
(237,35)
(326,88)
(256,145)
(361,208)
(171,328)

WITS Planetary Mission Operational Scenario



- Operators reside at JPL Rover Mission Control Center or at any location on the World Wide Web.
- WITS and AR and VR control station operators generate science targets and science commands for targets.
- Mission planner takes science command requests and generates daily mission command sequence to rover.
- Mission command sequence can be developed simultaneously by Web and JPL based scientists and mission planner.

References

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